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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

The scanning photoacoustic microscope has been further developed and experimental results of thermal wave scattering from subsurface flaws bave been compared with theoretical predictions.

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PHOTOACOUSTIC MICROSCOPY

FINAL REPORT

R. L. THOMAS, L. D. FAVRO AND P. K. KUO

SEPTEMBER 14, 1982

U. S. ARMY RESEARCH OFFICE

CONTRACT NO. DAAG 29-81-K-0113

WAYHE STATE UNIVERSITY

A. Statement of the Problem Studied

The objective of this research was to pursue additional developmental research on the technique of Scanning Photoacoustic Microscopy (SPAM), a new NDE technique which was initiated at WSU and had been first developed here under ARO support. A joint experimental/theoretical program of research was proposed, including instrumental development, initiation of studies in the time domain, and three-dimensional thermal diffusion and scattering calculations for subsurface flaws.

B. Summary of the Most Important Results

Considerable improvements have been achieved in the design of the photoacoustic microscope, including new sample cells, and better microcomputer hardware, firmware and software for the scan control and data acquisition. The ND:YAG laser system has been made operational and has been used to obtain preliminary data in the development of a time-domain photoacoustic microscope (pulse-echo thermal wave imaging). Scan control instrumentation has been developed for this instrument, as well as electronics for data acquisition in the time domain. Theoretical calculations of pulsed thermal wave propagation and scattering have been carried out for comparison with experiment.

Calculations for photoacoustic signals (cw) from model subsurface defects have been carried out and compared with experimental results. A key result is the theoretical prediction, and experimental verification that closed subsurface lateral cracks have a very characteristic photoacoustic phase signature which allows their discrimination from subsurface voids (or open cracks). Calculations have also been carried out for subsurface spherical voids and tilted closed cracks. These calculations themselves were made possible because of our development of a very general theorem for SPAM using gas-filled cells, which greatly simplifies the theoretical calculations of the effects of thermal wave scattering from arbitrarily shaped flaws in solids.

Because of the potential technological applications of our research, we were

invited to make presentations at the ASM/AIME Sponsored Symposium on Novel NDE Methods for Materials, held in Dallas, Texas, February 15-16, 1982, in addition to two U.S. Army sponsored symposia: The Track and Suspension R&D Symposium, Troy, Michigan, March 29-30, 1982 and the TACOM/Depot Conference on Nondestructive Inspection/Automatic Test Equipment, Warren, Michigan, May 19-20, 1982. Collaboration continued throughout the period of this Contract with Dr. Rose of TACOM, who is assembling a photoacoustic microscope in his laboratory.

Two Dissertations were approved during the period of this contract: "The Development of a Scanning Photoacoustic Microscope," John J. Pouch, Ph.D. Dissertation, Wayne State University, approved September 2, 1981, and "Surface and Subsurface Flaw Detection in Ceramic Silicon Carbide and Silicon Nitride Using Scanning Photoacoustic Microscopy," Lorretta J. Inglehart, M.Sc. Thesis, Wayne State University, approved March 11, 1982.

C. List of Publications

1. "Photoacoustic Phase Signatures of Closed Cracks," P. K. Kuo, L. D. Favro, L. J. Inglehart and R. L. Thomas, J. Appl. Phys. 53, 1258-1260 (1982).

2. "A Simplified Approach to Computations of Photoacoustic Signals in Gas-Filled Cells, P. K. Kuo and L. D. Favro, Appl. Phys. Lett. 40, 1012-1014 (1982).

3. "Photoacoustic Microscopy for NDE of Opaque Solids," R. L. Thomas, L. J. Inglehart, L. D. Favro and P. K. Kuo, submitted to Proc. ASM/AIME Sponsored Symposium on Novel NDE Methods for Materials, held in Dallas, Texas, February 15-16, 1982.

4. "Photoacoustic Microscopy for NDE of Metals and Ceramics" R. L. Thomas, L. J. Inglehart, L. D. Favro and P. K. Kuo, Proc. Institute of Acoustics (U.K.) Symposium in Acoustic Emission adn Photoacoustic Spectroscopy (1982).

5. "Applications of Photoacoustic Techniques to Nondestructive Evaluation and Imaging," R. L. Thomas, L. D. Favro, K. R. Grice, L. J. Inglehart, P. K. Kuo and J. Lhota Invited paper to be presented at the 1982 IEEE Ultrasonics Symposium, San Diego, California, October 27-29, 1982.

6. "Photoacoustic Microscopy," L. D. Favro, L. J. Inglehart, P. K. Kuo, J. J. Pouch, and R. L. Thomas, Proceedings of the DARPA/AFWAL Review of Progress in Quantitative NDE, Tech. Rept. AFWAL-TR-81-4080, pp. 236-238 (1981).

6. "The Application of the State-of-the-art NDE Techniques to Defect Detection in Silicon Carbide Structural Ceramics," M. Srinivasan, D. Lawler, D. Yuhas, L. Inglehart and R. L. Thomas (to be published in Proceedings of the AF/DARPA Review of Progress in Quantitative NDE, University of Colorado, August 2-7, 1981).

7. "Experimental and Theoretical Characterization of Near Surface Cracks in Solids by Photoacoustic Microscopy," P. K. Kuo, L. J. Inglehart, L. D. Favro, and R. L. Thomas, Proc. 1981 IEEE Ultrasonics Symposium, 837-839 (1981).

8. "A General Theorem for Simplifying Calculations of Photoacoustic Signals in Gas-Filled Cells," P. K. Kuo, L. J. Inglehart, L. D. Favro, and R. L. Thomas, Proc. 1981 IEEE Ultrasonics Symposium, 788-790 (1981).

D. Scientific Personnel Supported by this Project and Degrees Awarded

R. L. Thomas, Professor

L. D. Favro, Professor

P. K. Kuo, Associated Professor

J. J. Pouch (Ph.D. 1981)

L. J. Inglehart (M.Sc. 1982)

J. Lhota, Graduate Research Assistant, Ph.D. Candidate

Lt. Col. K. R. Grice (On leave from faculty, U. S. Military Academy, Ph.D. Candidate, Graduate Research Assistant at no cost to the contract).